

RESULTS APPENDIX

Fracture Location and Classification

Twelve of the 16 studies used recognized classifications to describe the fractures.^{1,3,10-17,24,29} Seven used the Orthopaedic Trauma Association (OTA) classification system,^{3,10-12,16,17,29} while 2 used the Johner and Wruhs Classification^{13,14}—a similar but pre-dated classification. For the OTA classification, type A was the most common fracture type, comprising 71% to 92% (mean, 80%) of all fractures. Three studies simply described the fractures by their configuration (transverse, oblique, or spiral).^{1,15,24}

Four studies used the Tscherne classification to describe the soft tissue injury associated with the fractures.^{10-12,29} C1 was the most commonly reported grading, comprising 49% to 84% (mean, 71%) of all injuries. Seven studies included open fractures with their cohorts, with the proportion of these injuries ranging from 2% to 100% (mean, 21%; median, 5%).^{10,12,14,15,17,24,29} All such studies used the Gustillo classification to describe the severity of injury, with grade 1 injuries being the most common, comprising 15% to 100% (mean, 78%) of reported injuries. Three studies used the Winquist classification to describe the degree of fracture comminution.^{12,15,29} Most fractures had low degrees of comminution, with up to three-quarters being described as grade 0 or 1. Only 2 studies reported on the presence of fracture displacement, with the proportion of undisplaced fractures ranging from 15% to 21% (mean, 18%).^{12,24} Six studies reported on the location of the fracture, with between 42% to 87% (mean, 52.5%) being located at the mid-diaphyseal region.^{1,2,11,12,14,15} Eight studies reported on the presence of an associated fibular fracture, with the rate of concomitant fibular fracture ranging 44% to 100% (mean, 76%).^{2,3,10,12,24,26,28,29}

Quality Assessment of Studies

The mean CMS for all studies was 61.9 (range, 44–81) (Table 1 in Appendix, see below).^{1-3,10-17,24,26-29} For the studies reporting on surgical interventions, the mean CMS was 62.8 (range, 44–81).^{1-3,10-15,17,26-29} For the studies reporting on nonsurgical interventions, the mean CMS was 58.6 (range, 44–81).^{1-3,16,17,24,26,29}

The interobserver reliability for the CMS results between the 2 investigators was high, with an intraclass correlation coefficient of 0.89 (95%CI, 0.86-0.92).

Fracture Union

For cases managed surgically, the mean time to fracture union ranged from 11.3 to 30 weeks (mean, 19 weeks), and rate of union ranged from 89% to 100% (mean, 98%).^{1,3,10,11,13-15,28} For those managed with IM nailing, mean time to union ranged from 11.3 to 30 weeks (mean, 21.6 weeks), and rates of union ranged from 89% to 100% (mean, 94%).^{10,11,15,28} For those managed with IM nailing and cerclage wiring, time to clinical union did not exceed 12 weeks.¹³ For those managed with cerclage wiring and casting, union rate was noted to be 100%.¹⁴ For those managed with ORIF, the mean time to union was 16 weeks, with a union rate of 100%.¹

For cases managed nonsurgically, mean time to union ranged from 10 to 21 weeks (mean, 16 weeks), and rate of union ranged from 87 to 98% (mean, 95%).^{1,3,16,24} For those managed with cast alone, union rates ranged from 91% to 100% (mean, 98%); time to union ranged from 10 to 19 weeks.^{3,16} For those managed using Sarmiento bracing, mean time to union was 12.9 weeks, with a rate of union of 98%.²⁴ For those managed with MUA and casting, the rate of union was 87%, with a mean time to union of 21 weeks.¹

Few studies specified differences between clinical and radiological union, with the majority stating combined figures for both.^{1,3,11,13,15,24,28}

Table 1. Characteristics of the studies included in the systematic review

| Author (year) | Study Design | N ^a | Sex (% male) | Mean Age (range), y | Treatment (n) | Sport Activity | Mean Follow-up (range), mo | Coleman Score | Open Fractures, n (%) |
|---------------------------------------|--------------------------|----------------|--------------|---------------------|--|-------------------------------------|----------------------------|---------------|-----------------------|
| Abdel-Salam et al (1991) ¹ | Randomized Control Trial | 90 | 92.2 | 28.1 (18-46) | MUA and cast (45) ORIF (45) | Soccer (68) Rugby (22) | 36 (12-60) | 81 | 0 (0%) |
| Boden et al (1999) ² | Retrospective | 26 | 77.4 | 19.0 (7-27) | Cast (16) IM nailing (10) | Soccer (26) | 30 (3-102) | 49 | 0 (0%) |
| Chang et al (2007) ³ | Retrospective | 24 | 100.0 | 23 (15-29) | Cast (11) Reamed IM nailing (11) ORIF (2) | Soccer (24) | 72 (48-96) | 62 | 0 (0%) |
| Fankhauser et al (2004) ⁹ | Prospective | 20 | 100.0 | 28.1 (21-62) | Unreamed IM nailing (20) | Soccer (20) | 56.4 (34-100) | 80 | 4 (20%) |
| Gaebler et al (2011) ¹⁰ | Randomized Control Trial | 26 | 66.0 | 37.5 | Reamed IM nailing (12) Min reamed IM nailing (14) | Sports (26) | 12 (12-12) | 71 | 0 (0%) |
| Gaston et al (1999) ¹¹ | Prospective | 100 | 81.0 | 30.6 | Reamed IM nailing (100) | Soccer (45) | 12 (12-12) | 70 | 13 (13%) |
| Habernek (1991) ¹² | Prospective | 37 | 59.5 | 33.0 | Reamed IM Nail & Cerclage wire (37) | Skiing (37) | 27.6 (6-48) | 73 | 0 (0%) |
| Habernek et al (1989) ¹³ | Retrospective | 186 | 49.5 | 34.5 | Cerclage wire and cast (186) | Skiing (144) | 42 (12-72) | 69 | 6 (3%) |
| Keating et al (1997) ¹⁴ | Randomized Control Trial | 60 | 84.6 | 37.0 (16-88) | Reamed IM nailing (31) Unreamed IM nailing (29) | Sports (60) | 22 (14-54) | 77 | 60 (100%) |
| Khalid et al (2006) ¹⁵ | Retrospective | 23 | 91.3 | 18 (15-34) | Cast (23) | Sport (23) | 190 (182-198) | 54 | 0 (0%) |
| Lenahan et al (2003) ¹⁶ | Retrospective | 50 | 100.0 | 20.8 (16-33) | Cast (25) Reamed IM nailing (22) ORIF (3) | Soccer (25) Gaelic Football (15) | 30 (11-57) | 61 | 1 (3%) |
| Peter et al (1988) ²⁴ | Retrospective | 46 | 58.2 | 34.0 (17-79) | Cast and bracing (10) Traction and bracing (36) | Skiing (46) | 60 (12-120) | 66 | 1 (2%) |
| Robertson et al (2014) ²⁷ | Retrospective | 3 | 100.0 | 25.0 | Reamed IM nailing (3) | Rugby (3) | 30 (24-36) | 46 | 0 (0%) |
| Robertson et al (2012) ²⁶ | Retrospective | 15 | 100.0 | 23.9 | Cast (6) Reamed IM nailing (9) | Soccer (15) | 40 (34-46) | 44 | 0 (0%) |
| Salai et al (1988) ²⁸ | Retrospective | 2 | 100.0 | 24.5 (22-27) | Reamed IM nailing (2) | Soccer (1) Basketball (1) | 18 (12-24) | 44 | 0 (0%) |
| Shaw et al (1997) ²⁹ | Retrospective | 74 | 98.6 | 25.8 | Cast (29) Reamed IM nailing (24) External fixator (8) Not stated (13) | Soccer (74) | 78 (60-96) | 52 | 4 (5%) |

IM, intramedullary; ORIF, open reduction and internal fixation.

^aCases with suitable follow-up data included.

Table 2. Summary of clinical outcomes for the studies included in the systematic review

| Author (year) | Mean Return Time (range), wks | Mean Return Time (range) by Treatment Modality, wks | Return Rate, n (%) | Return Rate to Same Level, n (%) | Return Rate By Treatment Modality, n (%) | Time to Union (range), wks |
|---------------------------------------|-------------------------------|---|--------------------|----------------------------------|--|---|
| Abdel-Salam et al (1991) ¹ | 114.4 | MUA and cast: 182 ORIF: 52 | 84/90 (93) | NA | MUA and cast: 39/45 (87) ORIF: 45/45 (100) | MUA and Cast: 21 (12-40) (C/Ra) ORIF: 16 (14-25) (C/Ra) |
| Boden et al (1999) ² | 38 (8-130) | NA | 25/26 (96) | NA | NA | NA |
| Chang et al (2007) ³ | 25.3 | Cast: 27.6 Surgery: 23.3 | NA | NA | NA | Cast: 19 (15-23) (C/Ra) Surgery: 23.9 (20-28) (C/Ra) |
| Fankhauser et al (2004) ⁹ | 40.9 (22-103) | U IM nailing: 40.9 (22-103) | 14/20 (70) | 11/20 (55) | U IM nailing: 14/20 (70) | U IM nailing: 11.3 (8.4-14.7) (Ra) |
| Gaebler et al (2011) ¹⁰ | 31.5 (17-46) | R IM nailing: 29 (17-41) MR IM nailing: 34 (22-46) | 24/26 (92) | 24/26 (92) | R IM nailing: 10/12 (83) MR IM nailing: 14/14 (100) | R IM nailing: 17 (13-21) (C/Ra) MR IM nailing: 19 (10-28) (C/Ra) |
| Gaston et al (1999) ¹¹ | 40.8 | R IM nailing: 41.0 | NA | NA | NA | NA |
| Habernek (1991) ¹² | 12 | R IM nailing and cerclage wire: 12 | NA | NA | NA | R IM nailing cerclage wire: 12 (C/Ra) |
| Habernek et al (1989) ¹³ | 28.4 (22-36) | Cerclage wire and cast: 28.4 (22-36) | NA | NA | NA | NA |
| Keating et al (1997) ¹⁴ | NA | NA | 56/60 (93) | 38/60 (63) | R IM nailing: 29/31 (94) U IM nailing: 27/29 (93) | R IM nailing: 30 (10-51) (C/Ra) U IM nailing: 28.5 (6-52) (C/Ra) |
| Khalid et al (2006) ¹⁵ | NA | NA | 13/23 (57) | 3/23 (13) | Cast: 13/23 (57) | Cast: 10 (8-14) (C) 14 (10-17) (Ra) |
| Lenehan et al (2003) ¹⁶ | 49.9 (26-77) | NA | 21/40 (53) | 17/40 (43) | N/A | NA |
| Peter et al (1988) ²⁴ | 34.0 (13-103) | Cast/traction and brace: 34.0 (13-103) | 24/46 (52) | NA | Cast/Traction and brace: 24/46 (52) | Cast/traction and brace: 12.9 (8-25) (C/Ra) |
| Robertson et al (2014) ²⁷ | 45.2 | R IM nailing: 45.2 | 2/3 (67) | 2/3 (67) | R IM nailing: 2/3 (67) | NA |
| Robertson et al (2012) ²⁶ | 38.2 | Cast: 45 R IM nailing: 35 | 12/15 (80) | 11/15 (73) | Cast: 4/6 (67) R IM nailing: 8/9 (89) | NA |
| Salai et al (1988) ²⁸ | 53.5 (52-56) | R IM nailing: 53.5 (52-56) | 2/2 (100) | 2/2 (100) | R IM nailing: 2/2 (100) | R IM nailing: 13.5 (12-15) (C/Ra) |
| Shaw et al (1997) ²⁹ | 40 | R IM nailing: 48 External fixator: 55 | 69/74 (93) | 51/74 (69) | NA | NA |

C, clinical union; C/Ra, combined clinical and radiological union; IM, intramedullary; MR, minimally reamed; MUA, manipulation under anesthesia; NA, no data available; ORIF, open reduction and internal fixation; R, reamed; Ra, radiological union.

Table 3. Summary of the reintervention rates and complication rates for the studies included in the systematic review

| Author (year) | Re-Intervention Rate, n (%) | Reason for Reintervention | | | | | | | Compartment Syndrome, n (%) | Infection, n (%) | Malunion, n (%) |
|---------------------------------------|--|---------------------------|---------------------|---------------|-------------|----------------------|-------------|-------------------|----------------------------------|---------------------------------|---------------------------------|
| | | Displacement | Nonunion | Delayed Union | Refracture | Compartment Syndrome | Infection | Metalwork Removal | | | |
| Abdelm-Sala et al (1991) ¹ | MUA and cast: 13/45 (29) ORIF: 18/45 (40) | 5 MUA, 2 ORIF - | 6 BG - | - - | - - | - - | - - | - 18 ROM | 1/45 (2) 0/45 (0) | 1/45 (2) 2/45 (4) | 6/45 (13) 0/45 (0) |
| Boden et al (1999) ² | Cast: 8/16 (50) IM nailing: 4/10 (40) | 4 IMN, 1 EF - | - - | - 2 DYN&BG | 3 Cast - | - 2 FASC | - - | - - | 0/16 (0) 2/10 (20) | 0/16 (0) 0/10 (0) | 1/16 (6) 0/10 (0) |
| Chang et al (2007) ³ | Cast: 5/11 (45) Surgery: 1/13 (8) | 4 IMN - | 1 ORIF&BG - | - 1 DYN | - - | - - | - - | - - | 0/11 (0) 0/13 (0) | 0/11 (0) 0/13 (0) | 0/11 (0) 0/13 (0) |
| Fankhauser et al (2004) ⁹ | U IM nailing: 9/20 (45) | - | - | - | - | 4 FASC | 1 EN | 4 ROS | 4/20 (20) | 1/20 (5) | 0/20 (0) |
| Gaebler et al (2011) ¹⁰ | R IM nailing: 12/50 (24) MR IM nailing: 18/50 (36) | - - | - - | 1 EN 5 EN | - - | 11 FASC 13 FASC | - - | - - | 11/50 (22) 13/50 (26) | 5/50(10) 4/50 (8) | 2/50 (4) 3/50 (6) |
| Gaston et al (1999) ¹¹ | NA | - | - | - | - | - | - | - | NA | NA | NA |
| Habernek (1991) ¹² | R IM nailing and cerclage wire: 2/37 (5) | - | - | - | - | - | 1 EN | 1 RON | 1/37 (3) | 1/37 (3) | 3/37 (8) |
| Habernek et al (1989) ¹³ | Cerclage wire and cast: 186/186(100) | - | - | 8 Cast | 3 Cast | - | - | 186 ROM | 0/186 (0) | 6/186(3) | 13/186 (7) |
| Keating et al (1997) ¹⁴ | R IM nailing: 16/31 (52%) U IM nailing: 15/29 (52) | - - | 4 EN 5 EN | - - | - - | 1 FASC 2 FASC | 1 EN | 10 RON 8 RON | 1/31 (3) 2/29 (7) | 2/31 (6) 1/29 (3) | 2/31 (6) 1/29 (3) |
| Khalid et al (2006) ¹⁵ | Cast: 0/23 (0) | - | - | - | - | - | - | - | NA | NA | NA |
| Lenehan et al (2003) ¹⁶ | Cast: 1/25 (4) R IM nailing: 3/22 (14) ORIF: 0/3 (0) | - - - | 1 ORIF&BG - - | - - - | - - - | - 3 FASC - | - - - | - - - | 0/25 (0) 3/22 (14) 0/3 (0) | 0/25 (0) 1/22 (5) 0/3 (0) | 0/25 (0) 0/22 (0) 0/3 (0) |
| Peter et al (1988) ²⁴ | Cast/traction and brace: 3/46 (7) | - | 1 ORIF&BG | - | 2 Cast | - | - | - | 0/46 (0) | 1/46 (2) | 2/46 (4) |
| Robertson et al (2014) ²⁷ | R IM nailing: 1/3 (33) | - | - | - | - | - | - | 1 ROS | 0/3 (0) | 0/3 (0) | 0/3 (0) |
| Robertson et al (2012) ²⁶ | Cast: 0/6 (0) R IM nailing: 4/9 (44) | - - | - - | - - | - - | - 3 FASC | - - | - 1 ROS | 0/6 (0) 3/9 (33) | 0/6 (0) 0/9 (0) | 0/6 (0) 0/9 (0) |
| Salai et al (1988) ²⁸ | R IM nailing: 0/2 (0) | - | - | - | - | - | - | - | NA | NA | NA |
| Shaw et al (1997) ²⁹ | NA | - | - | - | - | - | - | - | NA | NA | NA |

BG, bone grafting; DYN, dynamization; EF, external fixation; EN, exchange nailing; FASC, fasciotomies for compartment syndrome; IM, intramedullary; IMN, intramedullary nail; MUA, manipulation under anesthesia; NA, no data available; ORIF, open reduction and internal fixation; ROM, removal of metalwork; RON, removal of IM nail; ROS, removal of screws.